Survey of Red Sea Urchin Populations In Queen Charlotte Strait, British Columbia, 2004

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SURVEY OF RED SEA URCHIN POPULATIONS IN QUEEN CHARLOTTE STRAIT, BRITISH COLUMBIA, 2004

by

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ABSTRACT

Atkins, M., Tzotzos, D., Hajas, W.C., and Campbell, A. 2006. Survey of red sea urchin populations in Queen Charlotte Strait, British Columbia, 2004. Can. Manuscr. Rep. Fish. Aquat. Sci. 2749: iii + 25 p.

A survey of red sea urchin populations was conducted in Queen Charlotte Strait (Pacific Fisheries Management, PFM sub-areas 12-11 and 12-16) during July, 2004. A total of 70 transects were surveyed by SCUBA divers, and 5566 red sea urchins were measured. There was no significant difference in estimated mean density (number/m^2) or biomass (g/m^2) between red sea urchins found inside (35 transects) and outside (35 transects) previously fished commercial bed areas. The density of red sea urchins in PFM sub-area 12-11 and in PFM sub-area 12-16 for red sea urchins of all sizes was 4.10/m^2 and 1.44/m^2, respectively, and for legal-sized red sea urchins (≥90 mm test diameter, TD) the density was 2.12/m^2 and 0.88/m^2, respectively. Overall, 26.3% of the total number of red urchins measured were ≤50mm TD whereas 52.5% were of legal size for the commercial fishery.

RÉSUMÉ

Atkins, M., Tzotzos, D., Hajas, W.C., and Campbell, A. 2006. Survey of red sea urchin populations in Queen Charlotte Strait, British Columbia, 2004. Can. Manuscr. Rep. Fish. Aquat. Sci. 2749: iii + 25 p.

Un relevé des populations d’oursins rouges a été réalisé en juillet 2004 dans le détroit de la Reine-Charlotte (sous-secteurs 12-11 et 12-16 de gestion des pêches du Pacifique). Au total, 70 transects ont été couverts par des plongeurs autonomes, qui ont mesuré 5566 oursins rouges. On n’a pas noté de différences significatives dans la densité moyenne estimée (nombre/m^2) ni dans la biomasse (g/m^2) entre les oursins rouges observés à l’intérieur (35 transects) et à l’extérieur (35 transects) de gisements auparavant exploités par la pêche commerciale. Dans les sous-secteurs 12-11 et 12-16, la densité des oursins rouges de toutes tailles était respectivement de 4,10/m^2 et de 1,44/m^2, et, pour les oursins de taille réglementaire (≥90 mm de diamètre du test, DT), la densité était respectivement de 2,12/m^2 et de 0,88/m^2. Dans l’ensemble, 26,3 % de tous les oursins rouges mesurés présentaient ≤50 mm DT, tandis que 52,5 % avaient la taille réglementaire pour la pêche commerciale.

INTRODUCTION

Red sea urchin (*Strongylocentrotus franciscanus*) distribution along the Pacific Coast of North America ranges from the southern tip of Baja California to Alaska (Kato and Schroeter 1985). Red sea urchins are found throughout shallow rocky subtidal habitats of British Columbia (Bernard 1977; Campbell and Harbo 1991). Sea urchins are commercially harvested for their gonads (roe), which are sold mainly in Japan. Coastal First Nations communities harvest sea urchins as part of their traditional food, social and ceremonial fisheries. The commercial red sea urchin fishery began in British Columbia (BC) in the early 1970's and the total landed value for the 2003-2004 season was $7.7 million (Juanita Rogers, pers. comm.), making the harvest of red sea urchins a valuable shellfish fishery in BC.

The commercial red sea urchin fishery history and management were described in Campbell and Harbo (1991), and Campbell et al. (1999a). Currently, several approaches are used in the management of the red sea urchin fishery, including: a minimum commercial harvest size of 90 mm test diameter (TD); area licensing; individual vessel quotas; area quotas; and limited licence entry. Quota calculations are based on estimates of urchin density from field surveys, and estimates of urchin bed areas. Density estimates are therefore essential to the assessment and management of the sea urchin fishery.

Early red sea urchin population surveys were conducted during the 1970's and 1980's by Breen et al. (1976, 1978), Adkins et al. (1981) and Sloan et al. (1987). Since 1993, red sea urchin population surveys have been conducted as a joint effort between the Pacific Urchin Harvesters Association (PUHA), First Nations, and Fisheries and Oceans Canada (DFO) (Jamieson et al. 1998a-d; Bureau et al. 2000a-d; Tzotzos et al. 2003a-d, 2006; Atkins et al. 2006a-g).

Fishery managers requested that red sea urchin surveys be conducted to update density and biomass estimates to help determine quotas. An area in Queen Charlotte Strait [Pacific Fishery Management (PFM) sub-areas 12-11 and 12-16] (Figure 1), was selected for survey through discussion between PUHA and DFO. The objective of this paper is to present detailed survey results and to estimate density and biomass of red sea urchins within and outside of commercially fished beds, for PFM sub-areas 12-11 and 12-16.

METHODS

SURVEY AREA AND TRANSECT LAYOUT

Survey efforts were concentrated in PFM sub-areas 12-11 and 12-16. Transect locations were selected and plotted on a marine chart prior to the survey to avoid bias in the field.

Transects were systematically placed along the shoreline with a random starting point. The ArcView GIS system was used to measure the shoreline length (SL) of the survey area, including islands. The position of the first transect was determined randomly, and subsequent transects were then spaced evenly along the shoreline. Areas of unsuitable red sea urchin habitat (e.g. sand and mud substrates) were excluded from the survey area. Since variation in urchin density was unlikely to match the spacing of the transects, the systematic sample was treated as a random sample of transects (Jamieson and Schwarz 1998).

SURVEY LOGISTICS

The survey was conducted from July 22-29, 2004, on the “King Clam”, a commercial red sea urchin fishing vessel. A crew of four people, consisting of three divers, one of which was a biologist, and the other two commercial red sea urchin harvesters, and a boat tender, was used for the survey.

DIVE SURVEY METHODS

In the field, locations of transects were determined from geographical references on the shoreline, and GPS. Exposure to wave action/current was recorded, for each transect, as one of nine codes: 0 = extreme shelter, 1 = minimal sea movement, 2 = well sheltered, 3 = occasional current, 4 = moderate exposure, 5 = strong tidal flow, 6 = high tide surge only, 7 = ground swell normal, 8 = high exposure. Leadline transects were laid perpendicular to shore from the boat, with a float attached to the deep end of each transect. Transects were laid out from shallow water to a depth of 15m (not corrected for tide), so transect length was dependent on the slope of the substrate and tide height. A two-diver team surveyed each transect from deep to shallow, one diver measured urchins while the other recorded data. A one meter squared (1 m^2) quadrat was placed on the bottom beside the transect and the test diameter (TD) of each red urchin present was measured, with callipers, to the nearest millimeter. If urchins could not be measured because they were inaccessible or broken/lost they were still counted, therefore the count of urchins in a quadrat may be higher than the number measured. The depth, substrate type, types of algae (and percent cover), shell length of abalone (*Haliotis kamtschatkana*), and TD of green (*S. droebachiensis*) and purple (*S. purpuratus*) sea urchins present in each quadrat were also recorded. The quadrat was then moved 2 m forward along the transect and the process was repeated, so that every second meter of the transect was surveyed. In cases where no urchins were found at the deep end of transects, observations of depth, substrate and algae were recorded only every 20 m to minimize dive time. In such cases, skipped quadrats were assigned zero values for urchin counts before the data were analysed. Once urchins were encountered, sampling was conducted every 2 m until the intertidal zone or the surface was reached.

DATA ANALYSIS

Habitat

Depth Categories

Gauge depths recorded by divers were corrected to depth below Chart Datum by subtracting tide height from the observed depths. Tide heights from the closest tide station located at Port Hardy were used to correct depths. The depth (m) for each quadrat was assigned to one of seven depth ranges: 1= <0.0m; 2= 0.0 - <2.5m; 3= 2.5 - <5.0m; 4= 5.0 - <7.5m; 5= 7.5 - <10.0m; 6= 10.0 -<12.5m; and 7= ≥12.5m.

Substrate

The divers recorded the dominant substrates (up to three) within each quadrat using one of nine generic codes: 1=smooth bedrock; 2=bedrock with crevices; 3=boulders, >30cm; 4=cobble, between 7.5cm and 30cm; 5=gravel, between 2cm and 7.5cm; 6=pea gravel, between 0.25-2cm; 7=sand; 8=shell; and 9=mud. For the analysis, the nine substrate codes were grouped into three main dominant categories: 1=rock (codes 1-5); 2=sand/shell (codes 6-8); and 3=mud (code 9). Each quadrat was assigned a dominant substrate code in order to determine the average percent of each dominant substrate.

Algae

Algal species were assigned to one of four categories based on growth characteristics: canopy (taller than 2m), understorey (30cm to 2m), turf (<30cm), and encrusting. The percent cover of algae in each category, for each quadrat, was calculated as the sum of the individual species' percent cover. Mean percent cover, by growth category, for each depth category was then calculated by averaging the quadrat percent covers over the depth category.

Estimation of Density and Biomass

Density and biomass estimates were calculated from transects that were located inside commercially harvested red sea urchin beds, for transects located outside of the harvested beds, and for all transects combined. Commercially harvested beds were defined as areas where commercial harvesting occurred between 1997 and 2000; therefore, areas defined as outside beds may have had fishing events prior to 1997 and/or after 2000. The process involved in defining the commercially harvested urchin beds was described by Campbell et al. (2001).

Density and biomass were estimated for red urchins in three size groups: a) all sizes, b) small urchins <50 mm TD, and c) urchins of legal size for the commercial fishery (≥90 mm TD). Estimates of mean density and biomass were calculated using the equations below.

Density estimates (d_{ts}) in number of red sea urchins per meter squared for each transect (t) and size group (s) were calculated as:

$$d_{ts} = \frac{N_{ct}}{a_t} * \frac{N_{mts}}{N_{mt}} \qquad (1)$$

where N_{ct} is the total number of red urchins counted on transect t, N_{mts} is the number of red urchins measured in size group s on transect t, N_{mt} is the total number of red urchins measured on transect t, and a_t is the surface area of all quadrats surveyed on the transect t. Here a_t is equal to the number of all quadrats surveyed on the transect since each quadrat had a surface area of 1 m^2.

Overall mean density ($\overline{d}_s$) for a PFM sub-area, for urchins of size group s, was estimated as a weighted mean of transect densities:

$$\overline{d_s} = \frac{\sum_t (d_{ts} * L_t)}{\sum_t L_t} \qquad (2)$$

where L_t is the length of transect t (Campbell et al. 1999b).

The standard error (s_d) of estimated mean density was calculated as:

$$s_d = \sqrt{1 - \frac{n}{T}} * \sqrt{\frac{\sum_t (d_{ts} * L_t - \overline{d}_s * L_t)^2}{n * (n-1) * \overline{L}^2}} \qquad (3)$$

where n is the number of transects surveyed, T is the total possible number of transects that can be sampled in a surveyed PFM sub-area and mean transect length ($\overline{L}$) was calculated as:

$$\overline{L} = \frac{\sum_t L_t}{n} \qquad \text{(Campbell et al. 1999b)} \qquad (4)$$

The expression $\sqrt{(1-(n/T))}$ was approximately equal to 1 since n was much smaller than T.

To calculate biomass, the weight of each red urchin measured was calculated using the relationship between urchin weight (W) in grams and test diameter (TD) in millimetres (Campbell et al. 1999b, 2000).

$$W = 0.0012659 * TD^{2.7068} \qquad n= 167,\ r^2=0.960 \qquad (5)$$

Biomass density (b_{ts} in grams per meter squared) of urchins of size group s, on a transect t, was estimated using a simplified form of the formula used in previous papers (Campbell et al. 2000). The formula was modified by Campbell et al. (1999b) to simplify computations:

$$b_{ts} = \frac{N_{ct}}{N_{mt}} * \frac{\sum W_{ts}}{a_t} \qquad (6)$$

where N_{ct} is the total number of red urchins counted on transect t, N_{mt} is the total number of red urchins measured on transect t, ΣW_{ts} is the sum of the weights of red urchins measured in size group s on transect t and a_t is the surface area of quadrats surveyed on the transect t.

Overall estimated mean biomass ($\overline{b_s}$) per surface area (grams per meter squared) was calculated as a weighted mean of transect biomass:

$$\overline{b_s} = \frac{\sum_t (b_{ts} * L_t)}{\sum_t L_t} \qquad \text{(Campbell et al. 1999b)} \qquad (7)$$

The standard error of estimated mean biomass was calculated using the same formula used for standard errors of density, but d_{ts} and $\overline{d_s}$ were substituted for b_{ts} and $\overline{b_s}$, respectively. The biomass estimate, for each PFM sub-area surveyed, was converted into quota recommendations for management purposes by Campbell et al. (2001).

A Kruskal Wallace Analysis (Systat 10) was used to compare red urchin densities between inside and outside of commercial beds overall and for each PFM sub-area.

Density and biomass estimates were also generated by depth.

Recruitment

Estimates of recruitment (R_T) of red sea urchin populations in BC have generally been expressed as a percentage of the total number of red sea urchins measured that were ≤50 mm TD (Adkins et al. 1981; Breen et al. 1976, 1978; Jamieson et al. 1998b, 1998c, 1998d; Sloan et al. 1987). For comparison purposes, the same method was used here. Recruitment was also calculated as a percentage of the total number of sub-legal red sea urchins (<90 mm TD) that were ≤50 mm TD (R_S). This method may provide a less biased measure of recruitment in areas where a commercial fishery has taken place, since the numbers of sea urchins ≥90 mm TD may be reduced due to the harvest (Tegner and Dayton 1981).

RESULTS

SURVEY LOGISTICS

In total, 70 transects were surveyed during eight dive days (Table 1, Figure 1). A total of 5568 red sea urchins were counted and 5566 were measured for TD in 1713 quadrats along the 70 transects. By PFM sub-area, 5079 and 487 red urchins were measured along 44 and 26 transects in sub-areas 12-11 and 12-16 respectively. The total transect length surveyed was 3356 m, for an average transect length of 50 m. Half

(35) of the transects were located on commercial red sea urchin beds recorded from 1997 to 2000 (Table 1).

SUBSTRATE AND HABITAT

All transects surveyed had a moderate or high exposure (Table 1). Of the total (1713) quadrats sampled, 69% had rock, 31% had sand/shell, and 1% had mud as the primary substrate. Of the 5568 red sea urchins counted, 82% were observed between 0.0 m and 7.5 m depth.

Canopy species of algae were scarce and found predominantly in depths <2.5m. Understorey algal abundance generally decreased with depth. Subtle trends suggested abundance of turf algae could be inversely related to red sea urchin density. Encrusting algae was consistently found at all depths surveyed (Table 2).

SIZE FREQUENCY DISTRIBUTION

The overall mean size of red sea urchins measured was 81.0 mm TD (Table 3, Figure 2). The smallest and largest red urchins measured were 5 mm and 196 mm TD, respectively. By PFM sub-area, the mean size of urchins found inside on outside of bed areas was 80.3 mm and 80.4 mm TD respectively in area 12-11, and 94.2 mm and 84.6 mm TD respectively in area 12-16.

The overall percentage of legal-sized red urchins (≥90 mm TD) was 52.5%, whereas the overall percentage of red urchins ≤50 mm TD (R_T) was 26.3%. Of the sublegal urchins, the percent that was ≤50 mm TD (R_S) was 55.4%. By PFM sub-area, the proportion of legal-sized red sea urchins in sub-area 12-11 and 12-16 was 51.5% and 62.2%, respectively, the percentage of red urchins ≤50 mm TD (R_T) was 27.0% and 19.7%, respectively, and the percentage of sublegals ≤50 mm TD (R_S) was 55.6% and 52.2%, respectively (Table 3).

Fifty-one percent (51%) of the red urchins sampled inside commercial bed areas (n=2209) were of legal size, as were 54% of the urchins sampled outside commercial bed areas (n=3357). In area 12-11, the percentage of the population surveyed inside and outside commercial bed areas that was of legal size was 49.2% and 53.1%, respectively. In area 12-16, the percentage of legal-sized red sea urchins found inside and outside commercial bed areas was 70.8% and 58.6%, respectively (Table 3).

Density and Biomass Estimates

For all transects combined, the estimated mean density and biomass for red sea urchins of all sizes were 3.25/m^2 and 901.1 g/m^2 respectively, and 1.73/m^2 and 791.9 g/m^2 for legal-sized red urchins (Table 4). Although differences in density and biomass between in and out of bed areas were observed for all size groupings, the differences were not significant (Table 5).

Overall (PFM sub-areas combined), for transects lying on red sea urchin beds, the estimated mean density of red urchins of all sizes was 2.83/m^2, and was 1.39/m^2 for legal-sized red urchins. For transects lying outside of commercial bed areas, the estimated mean density was 3.61/m^2 for red urchins of all sizes, and 2.01/m^2 for legal-sized red urchins. Inside bed areas, the estimated mean biomass of red sea urchins of all sizes was 756.4 g/m^2, and was 659.0 g/m^2 for legal-sized urchins; outside bed areas the estimated mean biomass was 1020.43 g/m^2 and 903.04 g/m^2, respectively (Table 4).

The estimated mean density for all sizes in PFM sub-area 12-11 was 4.10/m^2 and in sub-area 12-16 was 1.44/m^2; the mean density for legal-sized urchins was 2.12/m^2 and 0.88/m^2 respectively (Table 4). When comparing densities by PFM sub-areas between inside and outside of commercial bed areas, no statistical differences were found for any size group (Table 5).

The highest mean density and biomass of red sea urchins of any size category was observed in the 0.0–2.5m depth range both inside and outside of commercial bed areas (Tables 6 and 7), although no statistical tests were performed to confirm significance.

DISCUSSION

A similar survey was completed in PFM sub-areas 12-11 and 12-16 in 1994 (Jamieson et al. 1998d). Although the site locations were different from our survey, the estimated mean densities from both surveys can be cautiously compared. The estimated mean density of total red sea urchins (all sizes) observed in area 12-11 this survey (2004) was 4.10/m^2, which was similar to the 1994 estimate of 3.95/m^2. However, in PFM sub-area 12-16, the estimated density observed in 2004 (1.44/m^2) was nearly three times the density observed in 1994 (0.50/m^2). The increase in density may be due to areas surveyed, population growth and/or reduced fishing effort in PFM sub-area 12-16.

In PFM sub-area 12-16 mean TD of red sea urchins was larger inside known commercial bed areas than outside bed areas (Table 3). The larger mean size suggested that harvesters were not removing the larger adults in the area surveyed, or there was poor recruitment. In PFM sub-area 12-11, the mean TDs inside and outside of bed areas were virtually identical (Table 3).

Densities observed in PFM sub-area 12-11 were more than triple those observed in sub-area 12-16. Transects were located around islands and in or near bays in sub-area 12-11, these areas may offer better habitat and provide more protection against winter storms than the relatively straight shoreline along which the transects were primarily located in sub-area 12-16.

When comparing the density estimates from this survey to estimates from other recent surveys along the coast of BC, the density of red urchins (all sizes) in Queen

Charlotte Strait (3.25/m^2) was similar to sites in the neighbouring area 12-13 (3.18/m^2) (Tzotzos et al. 2003a), but higher than Johnstone Strait (1.79/m^2) (Bureau et al. 2000b), Robson Bight (0.80/m^2) (Atkins et al. 2006e), Campbell River (1.13/m^2) (Atkins et al. 2006f), and Comox/Denman/Horby (0.59/m^2) (Bureau et al. 2000a).

In both PFM sub-areas, for total red sea urchins (all sizes), both inside and outside of commercial bed areas, the highest density and biomass estimates were found at the depth range between 0 and 2.5m. This may have been due to the depth where food, algae and algal drift were most abundant combined with being the shallowest depths generally tolerated by red sea urchins.

Recruitment (R_T), in this study, was higher in PFM sub-area 12-11 (27.0%) than in PFM sub-area 12-16 (19.7%). Of the most recently analyzed surveys (2000-2004) in B.C., the highest levels of recruitment were observed in Laredo Channel in 2000 (31.7%) (Tzotzos et al. 2003c) and Fitz Hugh Sound in 2001 (30.7%) (Atkins et al. 2006g), but all others showed lower estimates of recruitment (Bureau et al. 2000a-d; and Tzotzos 2003a, b, d; Atkins et al. 2006a-f). In earlier surveys, Bernard (1977) and Sloan et al. (1987) found that red sea urchin recruitment in B.C. was generally low.

Numerous factors could influence recruitment in any given area including physical and oceanographic influences, predation on larvae and juveniles, and interactions between juveniles and adults (Kalvass 1992; Sloan et al. 1987).

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Table 1. Summary of transects surveyed during the July 22-29, 2004 red sea urchin (RSU) population survey in Queen Charlotte Strait. Density in number per square meter and biomass in grams per square meter. PFM = Pacific Fishery Management [sub-area]. Depths have been corrected for tides to chart datum. Exposure values: 4 = moderate exposure, 8 = high exposure. Check marks (✓) indicate transect lying within a known commercial RSU bed.

Transect	PFM Sub-area	Latitude	Longitude	Depth (m)		Exposure Value	Time		Total Time (minutes)	Transect Length(m)	Number Quadrats	Number RSU Counted	RSU Density	RSU Biomass	In Bed
				Minimum	Maximum		Start	End							
1	12-16	50 48.325	127 38.157	-0.82	10.70	8	09:55	10:01	6	13	7	0	0.00	0.00	✓
2	12-16	50 48.101	127 37.433	-0.70	10.73	8	15:40	16:01	21	15	8	54	6.75	2164.39	✓
3	12-16	50 47.507	127 35.727	-0.15	11.77	8	11:03	11:28	25	61	31	38	1.23	425.01	✓
4	12-16	50 47.488	127 35.363	-0.12	12.65	8	10:38	10:55	17	25	13	20	1.54	708.74	✓
5	12-16	50 47.447	127 34.970	0.12	11.31	8	10:04	10:24	20	59	30	24	0.80	210.75	✓
6	12-16	50 47.271	127 34.567	0.24	9.60	8	09:37	09:56	19	91	46	0	0.00	0.00	✓
7	12-16	50 47.107	127 34.266	1.22	11.83	8	09:10	09:24	14	43	22	10	0.45	128.74	✓
8	12-16	50 48.451	127 38.902	-0.18	10.06	8	10:21	10:49	28	23	12	69	5.75	1092.99	
9	12-16	50 48.131	127 37.787	-0.67	8.93	8	16:09	16:38	29	47	24	46	1.92	639.66	
10	12-16	50 48.021	127 37.111	-0.12	11.13	8	15:02	15:29	27	37	19	42	2.21	397.02	
11	12-16	50 47.912	127 36.760	1.25	12.19	8	14:24	14:51	27	23	12	61	5.08	1599.97	
12	12-16	50 47.784	127 36.393	-0.40	11.25	8	13:36	14:10	34	61	31	45	1.45	468.50	
13	12-16	50 47.637	127 36.037	0.91	11.67	8	11:41	12:01	20	47	24	23	0.96	378.37	
14	12-16	50 47.080	127 33.696	-0.24	11.03	8	08:25	08:57	32	33	17	57	3.35	1235.10	
21	12-11	50 52.012	127 38.919	0.24	10.55	8	11:33	12:33	60	111	56	317	5.66	1321.01	
22	12-11	50 51.695	127 38.788	-0.76	10.12	8	10:16	10:34	18	23	12	52	4.33	1953.93	✓
23	12-11	50 51.347	127 38.467	-0.52	10.33	8	09:32	09:49	17	17	9	52	5.78	1723.31	✓
24	12-11	50 51.086	127 38.238	-0.15	12.19	8	12:47	13:10	23	35	18	84	4.67	975.29	✓
25	12-11	50 50.223	127 37.875	-1.07	9.72	8	14:00	14:12	12	21	11	26	2.36	908.06	✓
26	12-11	50 49.773	127 37.615	-0.94	9.81	4	14:44	14:55	11	21	11	11	1.00	442.99	✓
27	12-16	50 49.549	127 37.074	-0.27	12.19	8	15:16	15:42	26	73	37	70	1.89	607.63	✓
28	12-11	50 52.109	127 37.947	-0.46	8.66	8	09:25	10:13	48	99	50	265	5.30	1498.05	
29	12-11	50 52.123	127 38.135	0.76	12.01	8	08:13	09:09	56	79	40	315	7.88	2293.33	
30	12-11	50 52.122	127 38.355	0.30	10.42	8	07:21	08:01	40	129	65	148	2.28	814.88	
31	12-11	50 51.804	127 38.865	-0.79	11.52	8	10:47	11:17	30	29	15	148	9.87	3470.18	✓
32	12-11	50 50.738	127 38.072	-0.15	11.61	8	13:22	13:46	24	41	21	91	4.33	793.51	
33	12-11	50 49.955	127 37.734	-1.01	9.81	8	14:18	14:35	17	21	11	44	4.00	772.53	
34	12-11	50 50.023	127 38.036	-1.46	9.30	8	08:45	09:14	29	37	19	71	3.74	816.75	
41	12-11	50 51.607	127 36.684	0.30	8.90	8	09:24	09:45	21	29	15	85	5.67	2302.43	✓
42	12-11	50 51.312	127 36.743	-0.79	9.20	8	14:20	15:01	41	83	42	121	2.88	827.76	✓
43	12-11	50 51.149	127 36.854	-0.49	9.69	8	13:31	14:09	38	61	31	83	2.68	756.70	✓
44	12-11	50 50.912	127 36.701	-0.52	10.06	8	10:45	11:54	69	97	49	283	5.78	1273.49	✓
45	12-11	50 50.298	127 36.809	-1.04	11.19	8	09:50	10:29	39	47	24	151	6.29	949.09	✓

continued next page

Table 1. continued

Transect	PFM	Latitude	Longitude	Depth (m)		Exposure	Time		Total Time	Transect	Number	Number RSU	RSU	RSU	In
	Sub-area			Minimum	Maximum		Start	End	(minutes)	Length(m)	Quadrats	Counted	Density	Biomass	Bed
46	12-11	50 50.316	127 36.813	-1.13	9.33	8	08:59	09:37	38	45	23	129	5.61	783.95	✓
47	12-11	50 50.205	127 36.766	-0.76	7.80	8	16:27	17:45	78	77	39	227	5.82	1419.74	✓
48	12-11	50 52.057	127 37.463	0.24	8.84	8	12:19	13:07	48	93	47	252	5.36	1260.37	
49	12-11	50 51.948	127 37.136	-1.01	7.65	8	11:14	12:06	52	71	36	298	8.28	2676.24	
50	12-11	50 51.799	127 36.855	0.88	6.98	8	09:56	10:53	57	93	47	262	5.57	1684.18	
51	12-11	50 51.542	127 36.699	-0.37	8.84	8	15:15	15:57	42	37	19	137	7.21	2320.28	
52	12-11	50 50.048	127 36.625	-0.76	10.88	8	14:58	16:06	68	47	24	304	12.67	1545.34	
53	12-11	50 49.854	127 36.624	-1.49	9.94	8	14:30	14:48	18	59	30	14	0.47	101.95	
54	12-11	50 49.755	127 36.778	-1.49	7.80	4	15:54	16:16	22	101	51	34	0.67	248.81	
61	12-11	50 50.364	127 35.660	-1.74	10.58	4	08:41	08:55	14	23	12	30	2.50	404.22	✓
62	12-11	50 50.240	127 35.722	-0.06	8.26	8	09:29	09:45	16	43	22	2	0.09	38.71	✓
63	12-11	50 50.177	127 35.759	-1.55	8.35	8	09:55	10:18	23	31	16	48	3.00	711.87	✓
64	12-11	50 49.964	127 35.797	-1.71	10.79	8	14:48	15:45	57	57	29	223	7.69	2475.00	✓
65	12-11	50 49.698	127 34.563	-0.64	5.33	8	11:06	11:28	22	57	29	44	1.52	613.50	✓
66	12-11	50 49.815	127 34.086	-2.38	5.52	8	10:41	10:50	9	61	31	0	0.00	0.00	✓
67	12-11	50 49.728	127 33.576	-2.07	9.48	8	09:06	09:27	21	31	16	32	2.00	505.06	✓
68	12-11	50 50.553	127 35.892	-2.13	9.17	8	16:14	16:52	38	59	30	138	4.60	1030.62	
69	12-11	50 49.918	127 35.650	-1.16	8.93	8	15:56	16:14	18	25	13	51	3.92	947.36	
70	12-11	50 49.836	127 35.225	-1.28	9.75	8	16:23	16:42	19	25	13	39	3.00	682.40	
71	12-11	50 49.872	127 34.868	-0.79	9.02	8	16:51	17:01	10	33	17	0	0.00	0.00	
72	12-11	50 49.810	127 34.810	-1.07	9.30	8	17:08	17:16	8	21	11	1	0.09	4.82	
73	12-11	50 49.706	127 34.823	-0.49	8.11	8	10:37	10:57	20	33	17	56	3.29	1482.29	
74	12-11	50 49.761	127 33.745	-1.07	8.93	8	9:37	10:02	25	39	20	15	0.75	164.57	
81	12-16	50 49.253	127 35.408	-1.46	8.93	8	11:09	11:22	13	35	18	25	1.39	435.59	✓
82	12-11	50 49.154	127 33.098	-2.04	8.14	8	13:43	14:09	26	73	37	49	1.32	434.14	✓
83	12-16	50 49.026	127 33.517	-1.25	9.36	8	14:23	14:34	11	27	14	1	0.07	0.14	✓
84	12-16	50 48.914	127 33.452	-2.01	8.14	8	11:00	11:14	14	41	21	4	0.19	104.69	✓
85	12-16	50 48.796	127 33.515	-3.05	7.68	8	11:24	11:36	12	33	17	9	0.53	274.53	✓
86	12-16	50 48.751	127 33.597	-1.98	8.44	8	11:45	12:02	17	39	20	52	2.60	513.91	✓
87	12-16	50 48.631	127 33.312	-1.43	7.41	8	12:32	12:43	11	13	7	24	3.43	1403.72	✓
88	12-11	50 49.110	127 33.757	-1.46	8.26	4	11:39	11:57	18	41	21	1	0.05	0.26	
89	12-16	50 49.020	127 33.845	-1.74	7.38	8	12:07	12:22	15	43	22	12	0.55	277.58	
90	12-16	50 48.669	127 33.458	-0.82	7.44	8	12:11	12:26	15	43	22	51	2.32	837.11	
91	12-16	50 48.608	127 33.008	-1.43	5.88	8	12:49	13:00	11	17	9	14	1.56	973.54	
92	12-16	50 48.606	127 32.716	-0.37	11.46	8	13:06	13:21	15	25	13	29	2.23	743.43	
93	12-16	50 48.874	127 32.645	-0.49	10.06	8	12:26	12:50	24	101	51	14	0.27	130.17	
94	12-11	50 48.954	127 32.692	-0.40	10.18	8	12:12	12:26	14	33	17	41	2.41	886.48	

Table 2. Mean number of red sea urchins (RSU), substrate category, and percent cover by algae for each depth category surveyed during the 2004 survey conducted in Queen Charlotte Strait. Depths have been corrected to chart datum. Substrate categories: 1 = rock, 2 = sand, 3 = mud; Canopy = tall, shading, surface-reaching algae. Understorey = 30cm to 2m in height. Turf = 5cm to 30cm in height. Encrusting = species forming a thin, crustose layer on rocks.

Depth Range (m)	Number of RSU		Number Of Quadrats	Mean Substrate Category	Mean Percent Cover by Algae			
	Total	Mean per Quadrat			Canopy	Understorey	Turf	Encrusting
PFM sub-area 12-11								
<0.0 m	292	2.9	101	1.00	8.8	53.6	32.7	51.4
0.0 - <2.5 m	1622	6.2	260	1.01	9.0	30.0	10.6	72.1
2.5 - <5.0 m	1607	4.3	371	1.27	1.7	13.6	4.6	55.7
5.0 - <7.5 m	978	2.8	351	1.32	0	18.5	4.4	44.5
7.5 - <10.0 m	465	1.7	281	1.72	0.2	9.6	15.2	21.9
10.0 - <12.5 m	115	2.2	53	1.49	0	7.4	23.2	31.8
≥12.5 m	None surveyed							
PFM sub-area 12-16								
<0.0 m	13	1.4	9	1.00	1.7	39.4	46.7	40.0
0.0 - <2.5 m	175	4.7	37	1.00	0.3	19.1	13.2	67.0
2.5 - <5.0 m	92	2.8	33	1.00	0	35.2	1.4	63.3
5.0 - <7.5 m	96	1.8	54	1.26	0	17.0	5.9	49.3
7.5 - <10.0 m	62	0.6	110	1.63	0	16.7	19.3	23.3
10.0 - <12.5 m	51	1.0	52	1.73	0	1.9	28.8	15.5
≥12.5 m	0	0	1	1.00	0	0	0	90.0
PFM sub-areas 12-11 and 12-16 combined								
<0.0 m	305	2.8	110	1.00	8.2	52.4	33.9	50.5
0.0 - <2.5 m	1797	6.1	297	1.01	7.9	28.5	10.9	71.4
2.5 - <5.0 m	1699	4.2	404	1.25	1.5	15.5	4.3	56.4
5.0 - <7.5 m	1074	2.7	405	1.31	0	18.3	4.6	45.1
7.5 - <10.0 m	527	1.3	391	1.69	0.1	11.6	16.3	22.3
10.0 - <12.5 m	166	1.6	105	1.61	0	4.7	26.0	23.7
≥12.5 m	0	0.0	1	1.00	0	0	0	90.0

Table 3. Number of red sea urchins measured and percent of urchins ≤50 mm TD and ≥90 mm TD for Pacific Fishery Management (PFM) sub-areas 12-11 and 12-16, surveyed during the 2004 population survey in Queen Charlotte Strait. R_T = percent of all red sea urchins that were ≤50 mm TD. R_S = percent of sublegal red sea urchins that were ≤50 mm TD.

PFM	Transects	Test Diameter (mm)			Numbers Measured			% Total Measured		% Sublegals
Sub- Area	Used	Mean	Minimum	Maximum	≤50 mm TD	≥90 mm TD	All Sizes	≤50 mm	>90 mm (R_T)	≤50 mm (R_s)
12-11	Within Beds	80.3	5	196	565	1016	2065	27.4	49.2	53.9
	Outside Beds	80.4	5	170	804	1601	3014	26.7	53.1	56.9
	All	80.3	5	196	1369	2617	5079	27.0	51.5	55.6
12-16	Within Beds	94.2	15	164	15	102	144	10.4	70.8	35.7
	Outside Beds	84.6	9	154	81	201	343	23.6	58.6	57.0
	All	87.4	9	164	96	303	487	19.7	62.2	52.2
Survey Total	Within Beds	81.2	5	196	580	1118	2209	26.3	50.6	53.2
	Outside Beds	80.8	5	170	885	1802	3357	26.4	53.7	56.9
	All	81.0	5	196	1465	2920	5566	26.3	52.5	55.4

Table 4. Mean density and biomass estimates of red sea urchins by size (test diameter, TD), within and outside of commercial beds, by Pacific Fishery Management sub-area, for the 2004 survey in Queen Charlotte Strait. Estimates are for transects within red sea urchin beds recorded between 1997 and 2000, for transects outside the beds, and for all transects combined. Values in brackets are ± S.E..

PFM Sub-Area	Transects Used	Number Of Transects	Sum of Transect Lengths (m)	Mean Density (no./m^2) for TD			Mean Biomass (g/m^2) for TD		
				≤50 mm	≥90 mm	All Sizes	≤50 mm	≥90 mm	All Sizes
12-11	Within Beds	21	961	1.09 (0.23)	1.83 (0.31)	3.83 (0.60)	19.2 (4.2)	853.6 (134.6)	993.0 (154.8)
	Outside Beds	23	1327	1.06 (0.28)	2.34 (0.38)	4.29 (0.65)	15.5 (3.7)	1041.8 (164.5)	1186.4 (179.8)
	All	44	2288	1.07 (0.19)	2.12 (0.26)	4.10 (0.45)	17.0 (2.8)	962.7 (112.0)	1105.2 (123.7)
12-16	Within Beds	14	568	0.27 (0.12)	0.66 (0.20)	1.13 (0.31)	4.2 (1.4)	329.9 (90.4)	361.5 (97.8)
	Outside Beds	12	500	0.38 (0.12)	1.13 (0.27)	1.80 (0.45)	6.5 (2.4)	534.7 (116.5)	580.1 (128.2)
	All	26	1068	0.32 (0.08)	0.88 (0.16)	1.44 (0.26)	5.3 (1.3)	425.8 (72.6)	463.8 (78.9)
Survey Total	Within Beds	35	1529	0.79 (0.17)	1.39 (0.24)	2.83 (0.47)	13.6 (3.0)	659.0 (104.4)	756.4 (120.7)
	Outside Beds	35	1827	0.87 (0.21)	2.01 (0.31)	3.61 (0.54)	13.0 (2.8)	903.0 (134.8)	1020.4 (149.0)
	All	70	3356	0.83 (0.14)	1.73 (0.21)	3.25 (0.37)	13.3 (2.1)	791.9 (89.6)	901.1 (100.1)

Table 5. Kruskal-Wallace test results comparing mean densities of red sea urchins by size groups between inside and outside commercial bed areas by PFM sub-area for the 2004 survey in Queen Charlotte Strait.

PFM Sub-area	P-values for Test Diameter		
	≤50 mm	≥90 mm	All Sizes
12-11	0.805	0.869	0.842
12-16	0.089	0.068	0.080
12-11 and 12-16	0.400	0.332	0.499

Table 6. Mean density estimates of red sea urchins by depth range for all urchins surveyed inside commercial beds, outside commercials beds, and total urchins surveyed, during the 2002 survey conducted near Campbell River. Values in brackets are ± S.E.

Depth Range (m)	Mean Density (number/m^2) by test diameter								
	≤50 mm			≥90 mm			All Sizes		
	In	Out	Total	In	Out	Total	In	Out	Total
PFM sub-area 12-11									
<0.0 m	0.44 (0.20)	1.11 (0.56)	0.78 (0.30)	1.58 (0.96)	1.60 (0.65)	1.59 (0.57)	2.86 (1.34)	3.91 (1.74)	3.40 (1.08)
0.0– <2.5 m	1.82 (0.45)	1.26 (0.52)	1.50 (0.35)	3.21 (0.65)	4.04 (1.00)	3.69 (0.64)	6.75 (1.27)	6.44 (1.48)	6.57 (1.00)
2.5 – <5.0 m	0.91 (0.16)	1.19 (0.23)	1.07 (0.15)	2.22 (0.47)	3.22 (0.37)	2.80 (0.33)	4.01 (0.75)	5.50 (0.54)	4.87 (0.49)
5.0 – <7.5 m	0.88 (0.30)	1.14 (0.42)	1.03 (0.27)	1.17 (0.27)	1.57 (0.30)	1.40 (0.22)	2.74 (0.69)	3.44 (0.73)	3.15 (0.52)
7.5 – <10.0 m	0.94 (0.39)	0.59 (0.30)	0.73 (0.24)	0.92 (0.30)	0.73 (0.22)	0.81 (0.18)	2.40 (0.72)	1.77 (0.59)	2.02 (0.46)
10.0 – <12.5 m	1.37 (0.60)	0.65 (0.68)	0.93 (0.50)	1.04 (0.41)	0.71 (0.54)	0.84 (0.38)	3.72 (0.91)	1.79 (1.42)	2.55 (1.08)
PFM sub-area 12-16									
<0.0 m	0.67 (0.67)	0.63 (0.52)	0.65 (0.42)	0.38 (0.26)	0.99 (0.72)	0.67 (0.35)	1.11 (0.89)	1.74 (1.29)	1.41 (0.74)
0.0– <2.5 m	0.55 (0.18)	0.60 (0.26)	0.57 (0.16)	1.85 (0.56)	2.70 (0.67)	2.30 (0.43)	3.10 (0.96)	4.05 (1.12)	3.61 (0.72)
2.5 – <5.0 m	0.78 (0.47)	0.35 (0.23)	0.53 (0.26)	1.04 (0.47)	1.12 (0.75)	1.08 (0.46)	2.25 (1.07)	1.85 (1.18)	2.02 (0.83)
5.0 – <7.5 m	0.25 (0.11)	0.44 (0.21)	0.34 (0.11)	0.83 (0.29)	0.76 (0.27)	0.80 (0.19)	1.28 (0.45)	1.39 (0.48)	1.33 (0.32)
7.5 – <10.0 m	0.02 (0.01)	0.15 (0.80)	0.07 (0.03)	0.18 (0.16)	0.55 (0.20)	0.32 (0.12)	0.23 (0.17)	0.84 (0.35)	0.46 (0.16)
10.0 – <12.5 m	0.00	0.42 (0.30)	0.18 (0.13)	0.35 (0.33)	1.03 (0.41)	0.64 (0.28)	0.43 (0.43)	1.53 (0.55)	0.89 (0.38)

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Table 6. continued.

Depth Range (m)	Mean Density (number/m^2) by test diameter								
	≤50 mm			≥90 mm			All Sizes		
	In	Out	Total	In	Out	Total	In	Out	Total
PFM sub-area 12-11 and 12-16 combined									
<0.0 m	0.51 (0.25)	0.97 (0.42)	0.74 (0.24)	1.19 (0.67)	1.42 (0.51)	1.31 (0.42)	2.29 (0.98)	3.28 (1.30)	2.79 (0.80)
0.0 – <2.5 m	1.48 (0.33)	1.11 (0.40)	1.27 (0.27)	2.84 (0.50)	3.72 (0.79)	3.34 (0.50)	5.76 (0.97)	5.88 (1.17)	5.83 (0.78)
2.5 – <5.0 m	0.88 (0.16)	0.99 (0.22)	0.94 (0.14)	1.95 (0.39)	2.73 (0.50)	2.40 (0.34)	3.60 (0.64)	4.66 (0.78)	4.21 (0.53)
5.0 – <7.5 m	0.68 (0.21)	0.97 (0.32)	0.84 (0.20)	1.06 (0.20)	1.37 (0.25)	1.24 (0.17)	2.28 (0.50)	2.95 (0.59)	2.65 (0.40)
7.5 – <10.0 m	0.44 (0.19)	0.45 (0.20)	0.44 (0.14)	0.52 (0.17)	0.67 (0.16)	0.60 (0.12)	1.22 (0.36)	1.46 (0.41)	1.34 (0.27)
10.0 – <12.5 m	0.44 (0.26)	0.53 (0.35)	0.48 (0.21)	0.57 (0.29)	0.87 (0.35)	0.72 (0.22)	1.48 (0.67)	1.66 (0.71)	1.57 (0.48)

Table 7. Biomass estimates of red sea urchins by depth range for all urchins surveyed inside commercial beds, outside commercials beds, and total urchins surveyed, during the 2002 survey conducted near Campbell River. Values in brackets are ± S.E.

Depth Range (m)	Mean Biomass (g/m^2) by test diameter								
	≤50 mm			≥90 mm			All Sizes		
	In	Out	Total	In	Out	Total	In	Out	Total
PFM sub-area 12-11									
<0.0 m	10.89 (4.83)	18.35 (9.23)	14.71 (5.21)	754.64 (435.79)	808.13 (309.82)	782.02 (261.04)	878.59 (481.46)	989.95 (384.83)	935.70 (301.18)
0.0– <2.5 m	38.81 (10.11)	20.29 (7.38)	28.11 (6.07)	1547.71 (299.02)	1908.01 (460.80)	1755.98 (294.44)	1814.36 (346.97)	2086.95 (492.46)	1971.93 (318.12)
2.5 – <5.0 m	14.22 (3.23)	17.72 (2.86)	16.23 (2.15)	1031.13 (212.40)	1388.89 (154.79)	1236.90 (141.52)	1166.13 (237.80)	1574.19 (159.05)	1400.84 (153.24)
5.0 – <7.5 m	12.47 (4.46)	14.37 (5.60)	13.59 (3.73)	515.64 (121.20)	651.41 (129.62)	595.22 (91.88)	618.64 (142.48)	770.68 (147.33)	707.76 (105.34)
7.5 – <10.0 m	15.43 (7.99)	7.82 (3.82)	10.88 (3.90)	429.90 (133.19)	296.92 (91.47)	350.39 (76.74)	510.41 (145.24)	367.47 (108.96)	424.95 (87.56)
10.0 – <12.5 m	33.85 (17.43)	11.88 (12.89)	20.48 (11.25)	338.33 (145.01)	272.12 (212.30)	298.04 (140.05)	584.29 (166.49)	343.37 (252.08)	437.67 (183.65)
PFM sub-area 12-16									
<0.0 m	6.45 (6.39)	10.49 (8.62)	8.36 (5.09)	260.01 (172.25)	458.02 (327.19)	353.56 (171.13)	269.44 (178.32)	480.67 (343.24)	369.24 (178.84)
0.0– <2.5 m	14.55 (4.86)	13.19 (5.92)	13.82 (3.81)	915.00 (263.31)	1397.24 (342.56)	1172.06 (212.47)	1021.16 (295.83)	1510.95 (369.99)	1282.25 (231.63)
2.5 – <5.0 m	9.78 (5.80)	4.59 (2.72)	6.79 (3.17)	538.59 (248.06)	492.39 (317.49)	511.96 (208.46)	602.21 (279.27)	545.03 (351.34)	569.25 (232.16)
5.0 – <7.5 m	3.62 (1.46)	8.23 (4.28)	5.90 (2.23)	419.26 (135.35)	340.75 (124.11)	380.41 (92.32)	450.57 (147.25)	378.89 (132.19)	415.10 (99.11)
7.5 – <10.0 m	0.02 (0.02)	1.79 (1.05)	0.70 (0.37)	84.42 (79.17)	269.46 (100.34)	155.17 (60.98)	88.61 (81.43)	292.13 (110.03)	166.42 (63.97)
10.0 – <12.5 m	0.00	5.95 (5.84)	2.49 (2.35)	152.25 (129.02)	424.88 (164.90)	266.42 (112.73)	168.80 (146.64)	436.17 (164.80)	280.76 (119.79)

Table 7. continued.

Depth Range (m)	Mean Biomass (g/m^2) by test diameter								
	≤50 mm			≥90 mm			All Sizes		
	In	Out	Total	In	Out	Total	In	Out	Total
PFM sub-area 12-11 and 12-16 combined									
<0.0 m	9.45 (3.86)	16.07 (7.02)	12.76 (3.96)	594.05 (305.76)	706.51 (241.49)	650.33 (192.21)	680.82 (338.98)	842.13 (294.36)	761.55 (221.29)
0.0– <2.5 m	32.25 (7.45)	18.62 (5.79)	24.52 (4.64)	1376.67 (229.24)	1787.52 (362.63)	1609.53 (228.97)	1599.93 (266.75)	1951.07 (388.03)	1798.95 (247.96)
2.5 – <5.0 m	13.19 (2.81)	14.67 (2.90)	14.04 (2.03)	917.18 (175.92)	1180.68 (211.01)	1068.82 (145.52)	1035.67 (197.41)	1335.17 (231.48)	1208.02 (160.56)
5.0 – <7.5 m	9.69 (3.16)	12.90 (4.37)	11.49 (2.81)	485.35 (91.64)	576.64 (107.15)	536.58 (72.70)	565.82 (106.19)	676.38 (121.80)	627.87 (83.20)
7.5 – <10.0 m	7.09 (3.60)	5.83 (2.56)	6.46 (2.19)	242.97 (80.52)	287.88 (68.98)	265.62 (52.48)	282.18 (86.16)	342.66 (81.19)	312.68 (58.60)
10.0 – <12.5 m	10.80 (6.90)	8.93 (6.66)	9.87 (4.70)	211.61 (105.09)	348.08 (141.20)	279.39 (86.02)	301.34 (136.84)	389.52 (151.63)	345.13 (100.15)

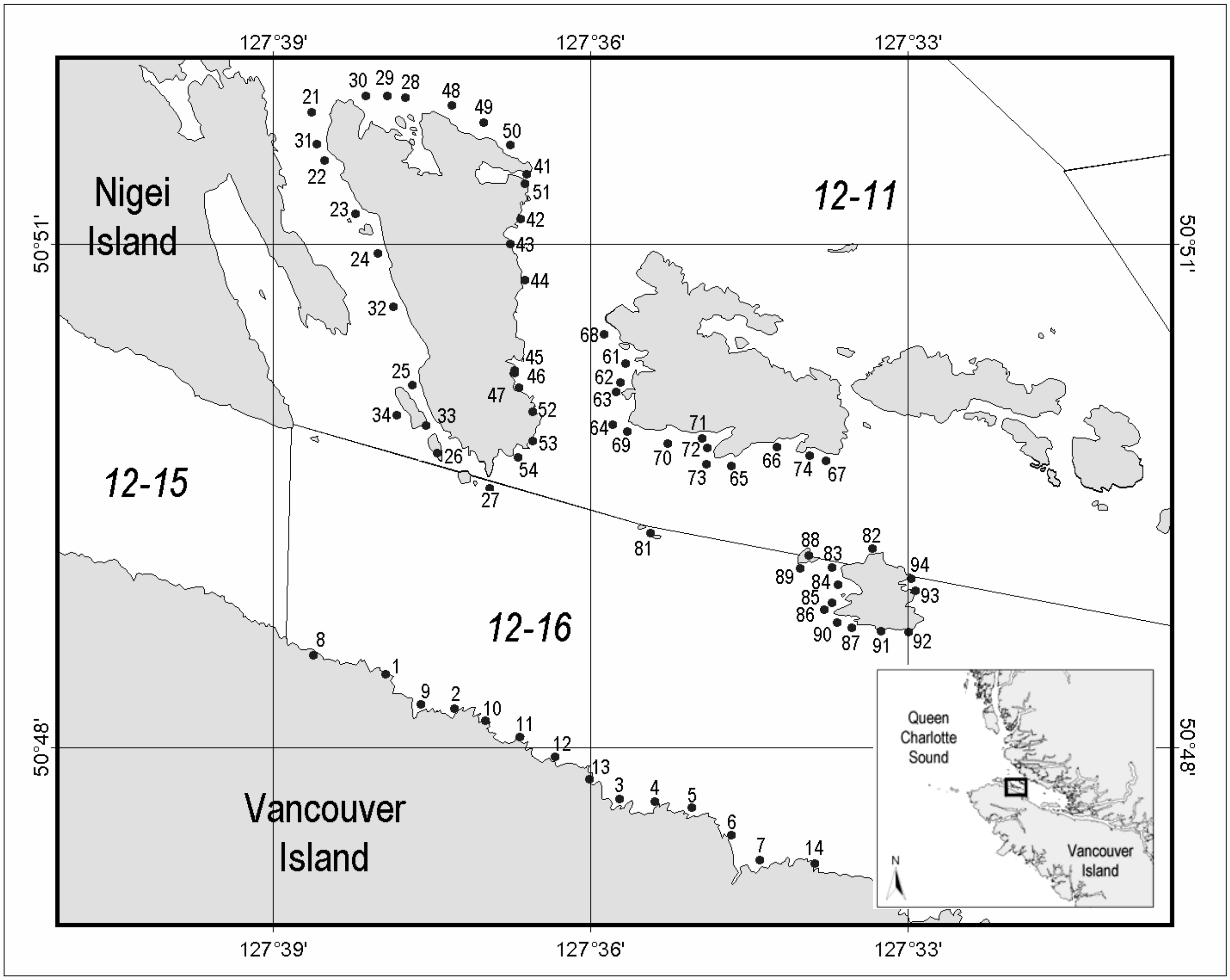

Figure 1. Map of survey area and transect locations for the red sea urchin population survey conducted in Queen Charlotte Strait, 2004. Hyphenated numbers indicate Pacific Fisheries Management sub-areas and other numbers indicate transects. Inset map indicates survey location.

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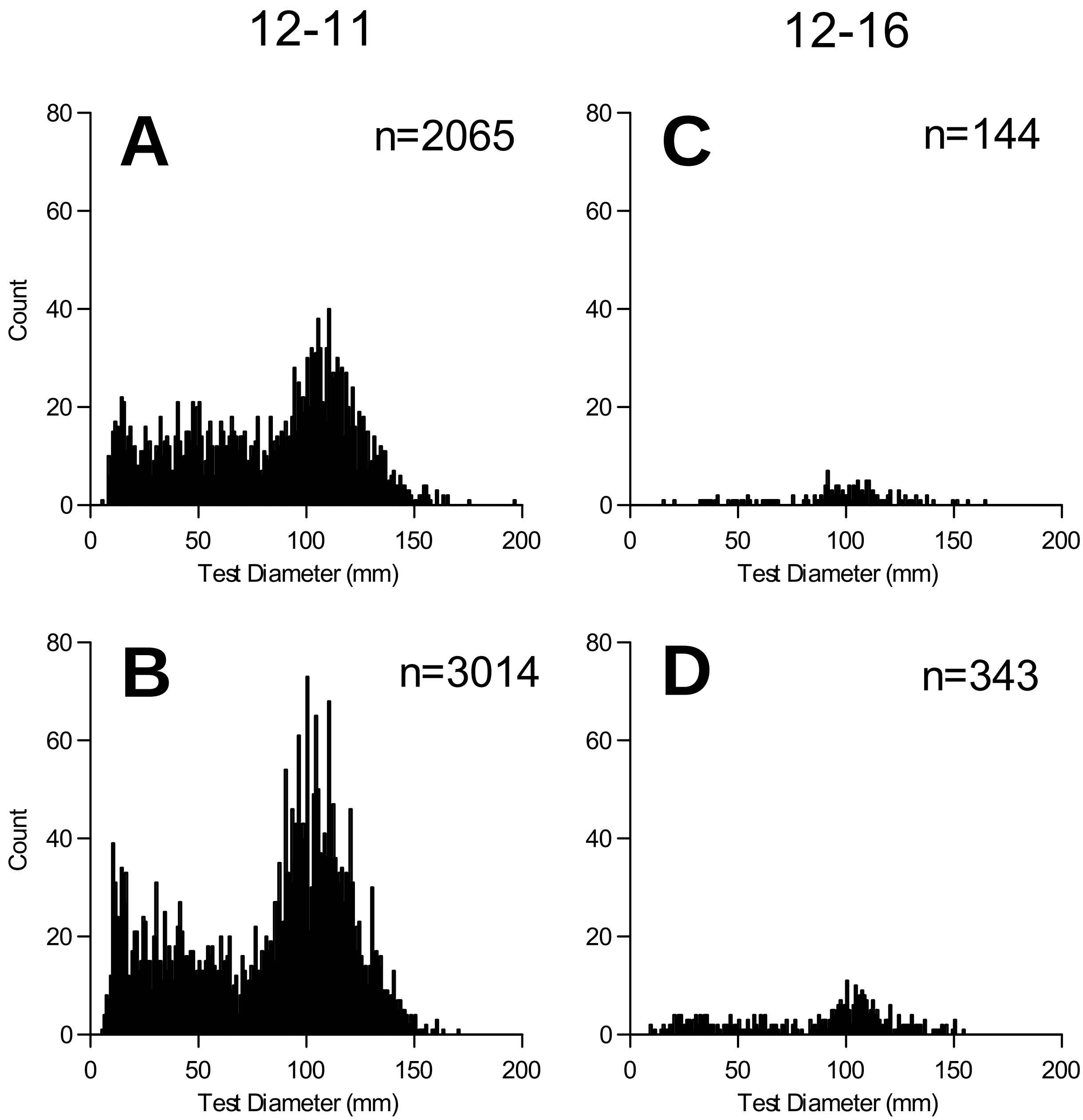

Figure 2. Size frequency distribution of red sea urchins measured inside (A,C) and outside (B,D) of commercial bed areas on all transects during the 2004 survey in Queen Charlotte Strait. Pacific Management sub-areas are indicated above the figures. n= number of red sea urchins measured for test diameter.